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**Wang**

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(54) **POWER CONVERTER AND OPERATING METHOD THEREOF**


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(51) **Int. Cl.**

***G05F 1/56*** (2006.01)
***H02M 3/158*** (2006.01)
*G05F 1/565* (2006.01)

(52) **U.S. Cl.**

CPC ............ ***H02M 3/158*** (2013.01); ***H02M 3/1584*** (2013.01); *G05F 1/565* (2013.01)

(58) **Field of Classification Search**

CPC .................................... G05F 1/10; G05F 1/56
USPC .................. 323/268, 271, 272, 282–285, 288
See application file for complete search history.



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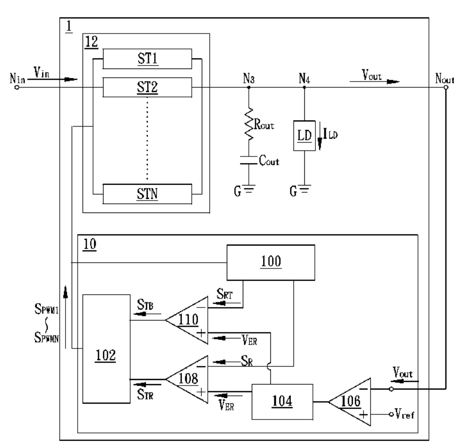
(57) **ABSTRACT**


A power converter includes a ramp generating unit, a first comparator, a second comparator, and a pulse width modulation (PWM) signal generating unit. The ramp generating unit provides a ramp signal. The first comparator receives the ramp signal and a control signal to provide a normal operation control signal. The second comparator receives the ramp signal and the control signal to provide a dynamic response control signal. The PWM signal generating unit generates a PWM signal according to the normal operation control signal or dynamic response control signal. When the control signal is higher than a threshold of ramp signal, the second comparator provides the dynamic response control signal to the PWM signal generating unit to control it to adjust a duty cycle of the PWM signal.


**13 Claims, 10 Drawing Sheets**



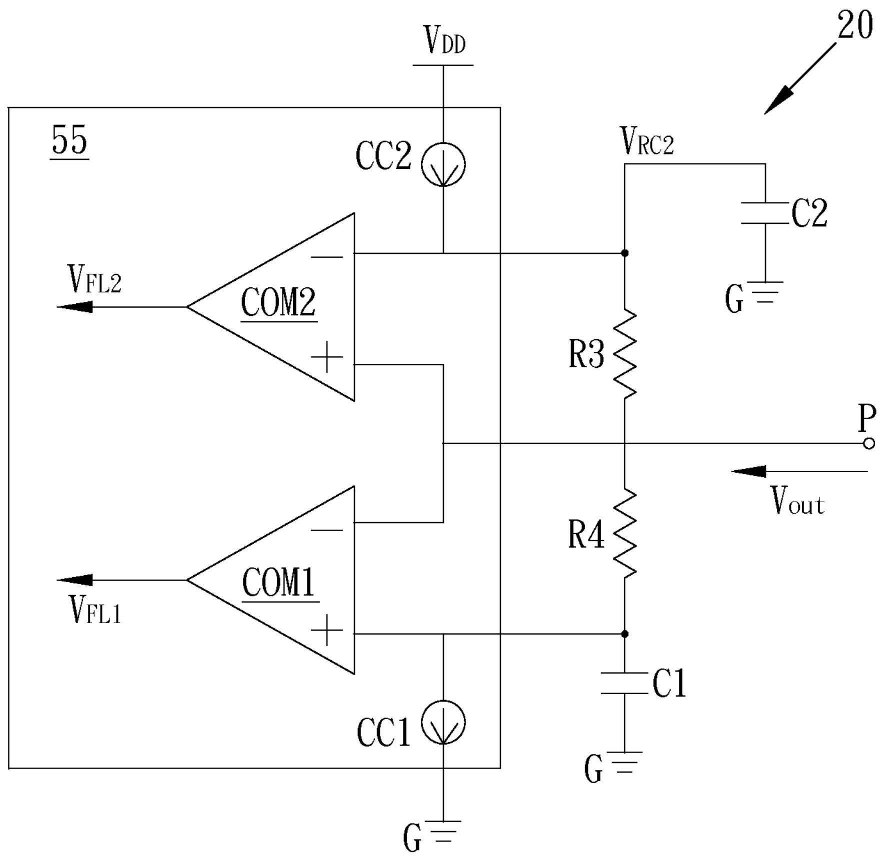
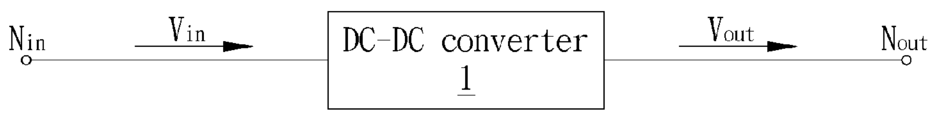
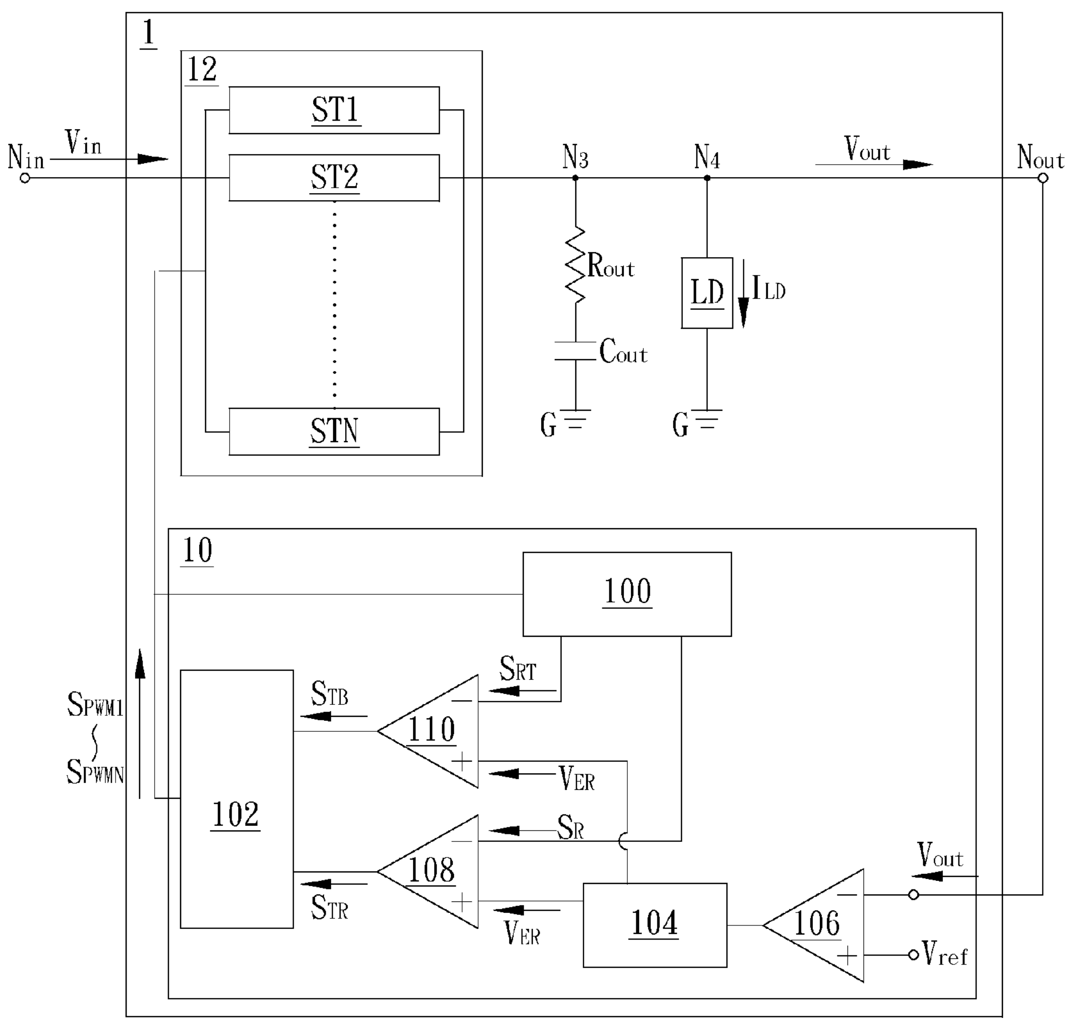



FIG. 1 (PRIOR ART)



$N_{in}$
$V_{in}$
DC-DC converter
1
$V_{out}$
$N_{out}$


FIG. 2A



1
12
ST1
ST2
STN
$N_{in}$
$V_{in}$
$N_3$
$N_4$
$V_{out}$
$N_{out}$
$R_{out}$
$C_{out}$
LD
$I_{LD}$
G
G
10
100
102
104
106
108
110
$S_{RT}$
$S_{TB}$
$V_{ER}$
$S_R$
$S_{TR}$
$V_{ER}$
$V_{out}$
$V_{ref}$
$S_{PWM1}$
$S_{PWMN}$


FIG. 2B

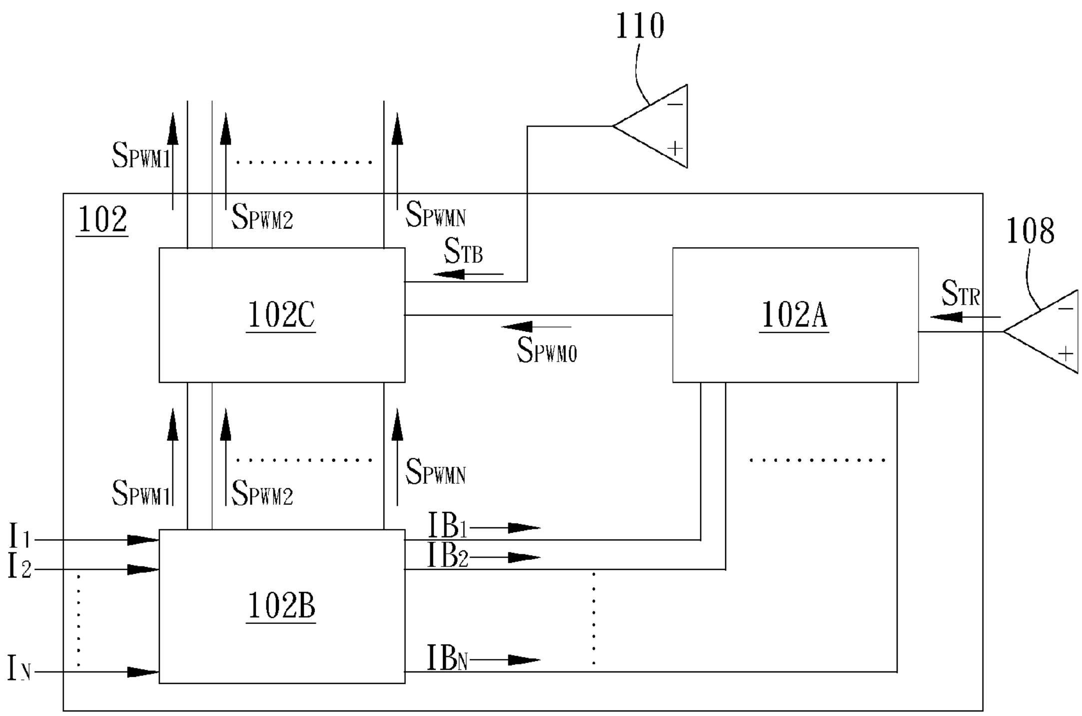

110
SPWM1
SPWM2
SPWMN
102
108
STB
STR
102C
102A
SPWM0
SPWM1
SPWM2
SPWMN
I1
I2
IN
IB1
IB2
IBN
102B

FIG. 3

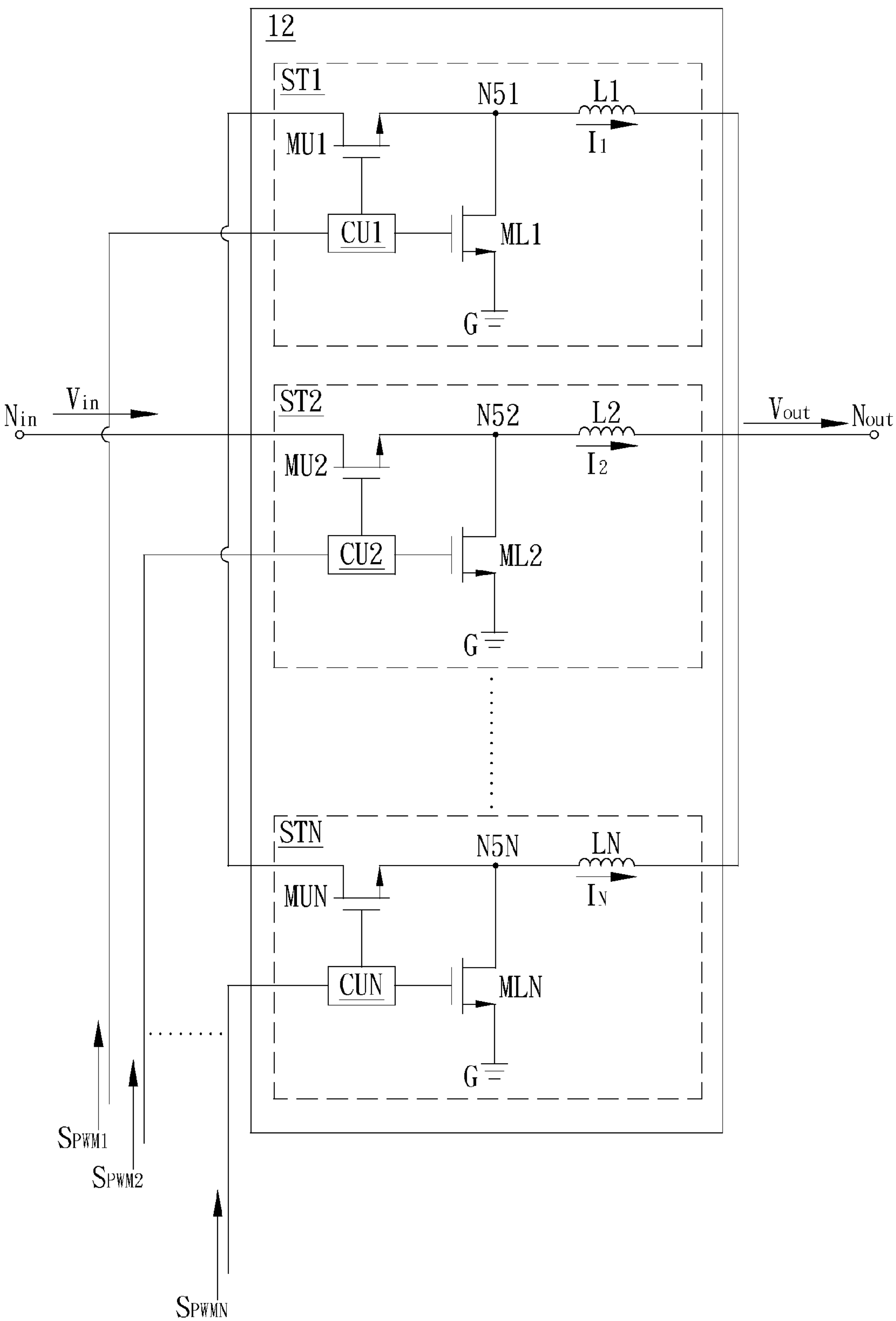

12
ST1
N51
L1
MU1
I1
CU1
ML1
G
ST2
Vin
Nin
N52
L2
Vout
Nout
MU2
I2
CU2
ML2
G
STN
N5N
LN
MUN
IN
CUN
MLN
G
SPWM1
SPWM2
SPWMN

FIG. 4

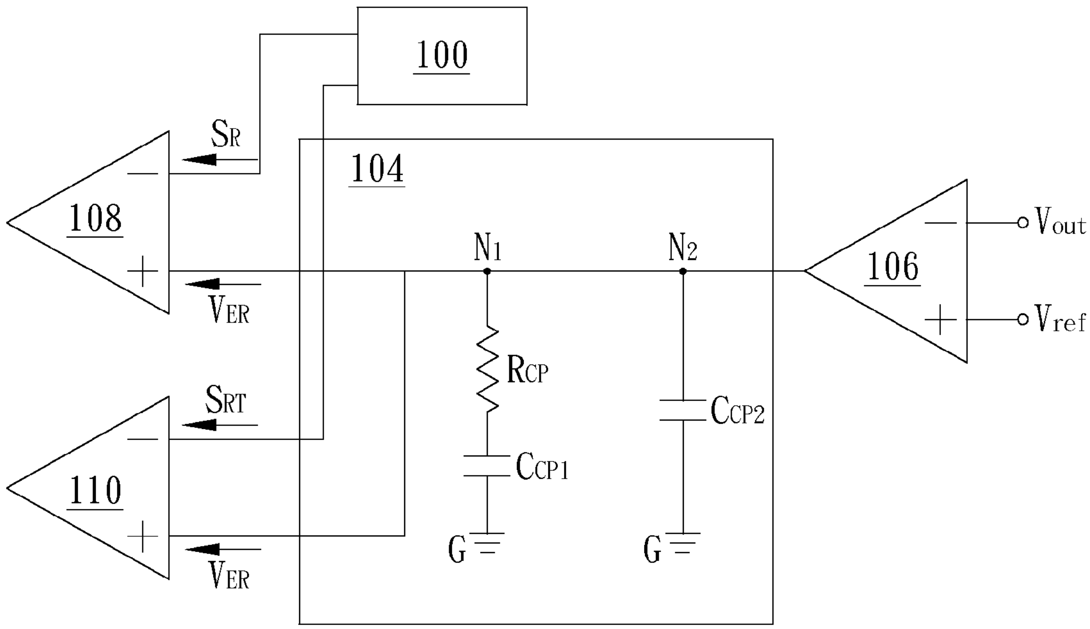

100
104
108
110
106
$S_R$
$S_{RT}$
$V_{ER}$
$V_{ER}$
$N_1$
$N_2$
$R_{CP}$
$C_{CP1}$
$C_{CP2}$
G
G
$V_{out}$
$V_{ref}$

FIG. 5

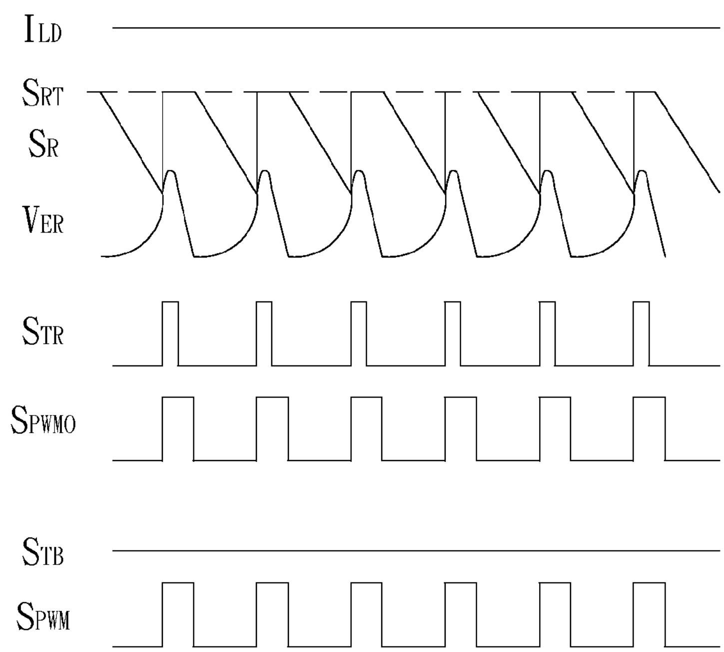

$I_{LD}$
$S_{RT}$
$S_R$
$V_{ER}$
$S_{TR}$
$S_{PWMO}$
$S_{TB}$
$S_{PWM}$

FIG. 6A

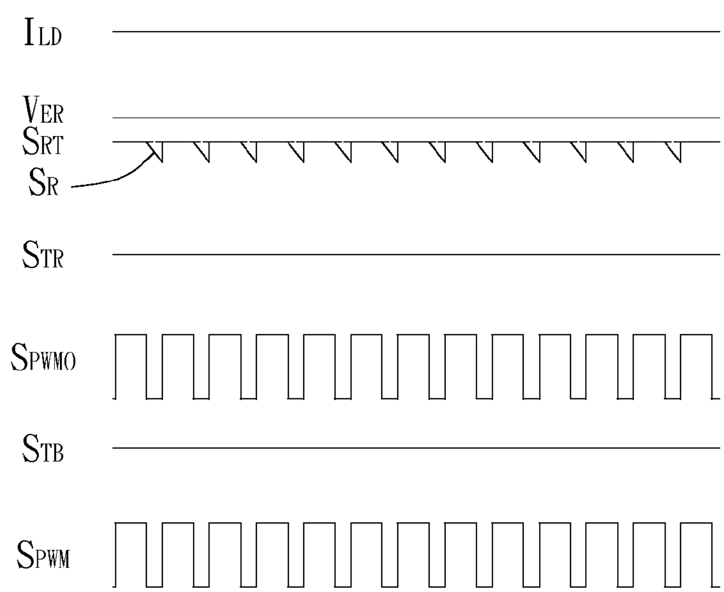
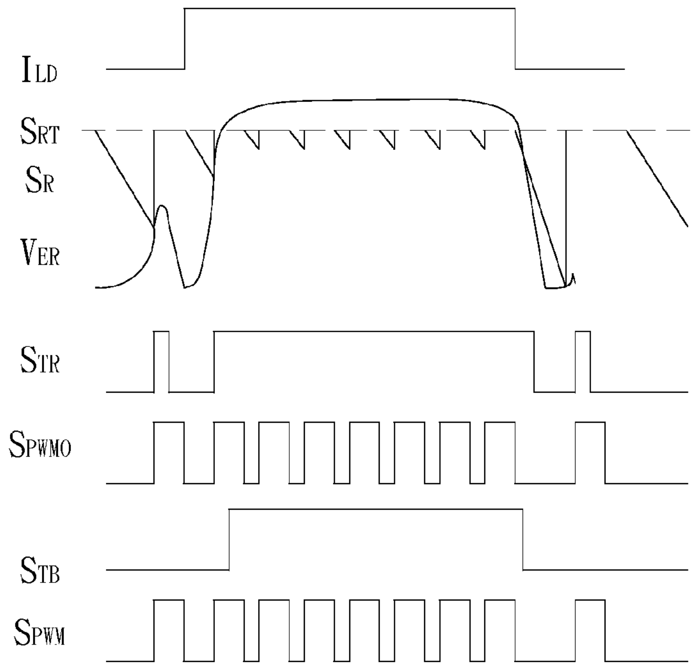
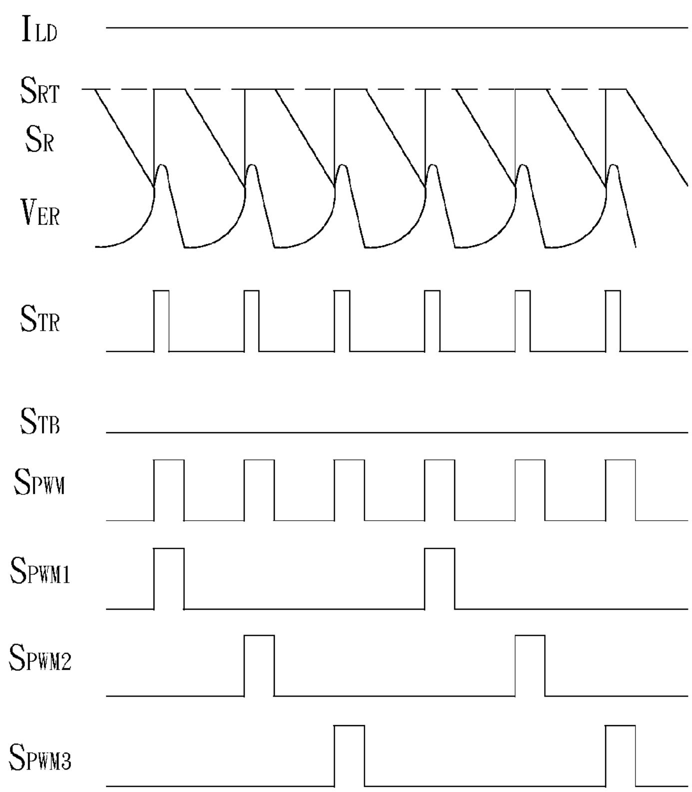

$I_{LD}$
$V_{ER}$
$S_{RT}$
$S_R$
$S_{TR}$
$S_{PWMO}$
$S_{TB}$
$S_{PWM}$

FIG. 6B



ILD
SRT
SR
VER
STR
SPWM0
STB
SPWM


FIG. 6C



ILD
SRT
SR
VER
STR
STB
SPWM
SPWM1
SPWM2
SPWM3


FIG. 7A

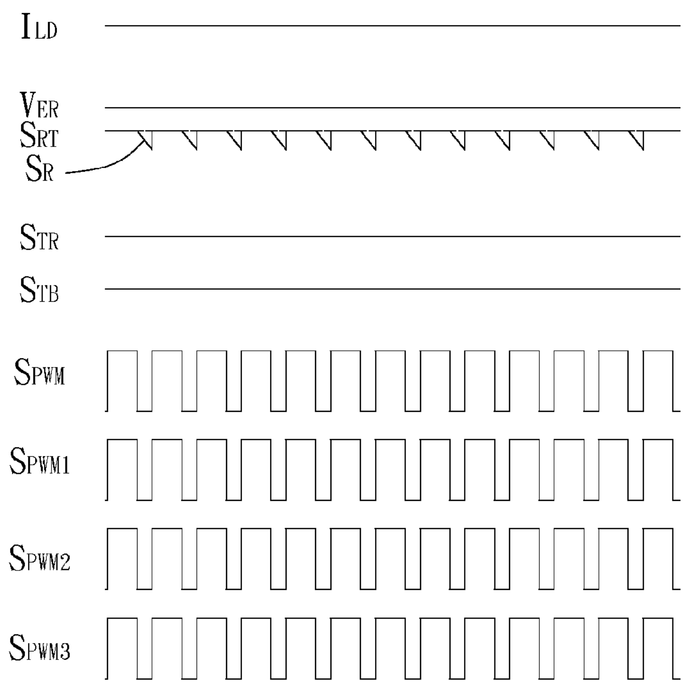

ILD
VER
SRT
SR
STR
STB
SPWM
SPWM1
SPWM2
SPWM3

FIG. 7B

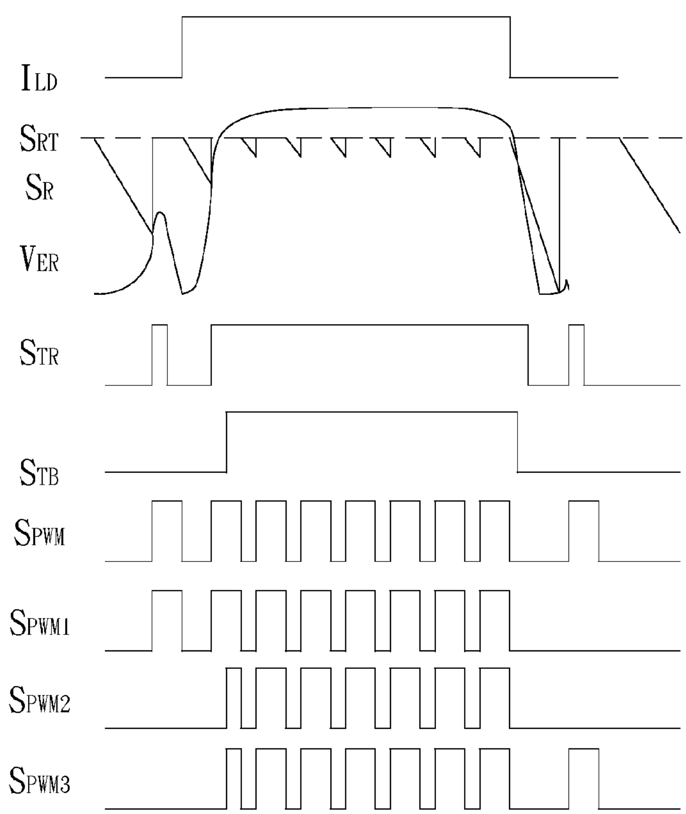

ILD
SRT
SR
VER
STR
STB
SPWM
SPWM1
SPWM2
SPWM3

FIG. 7C

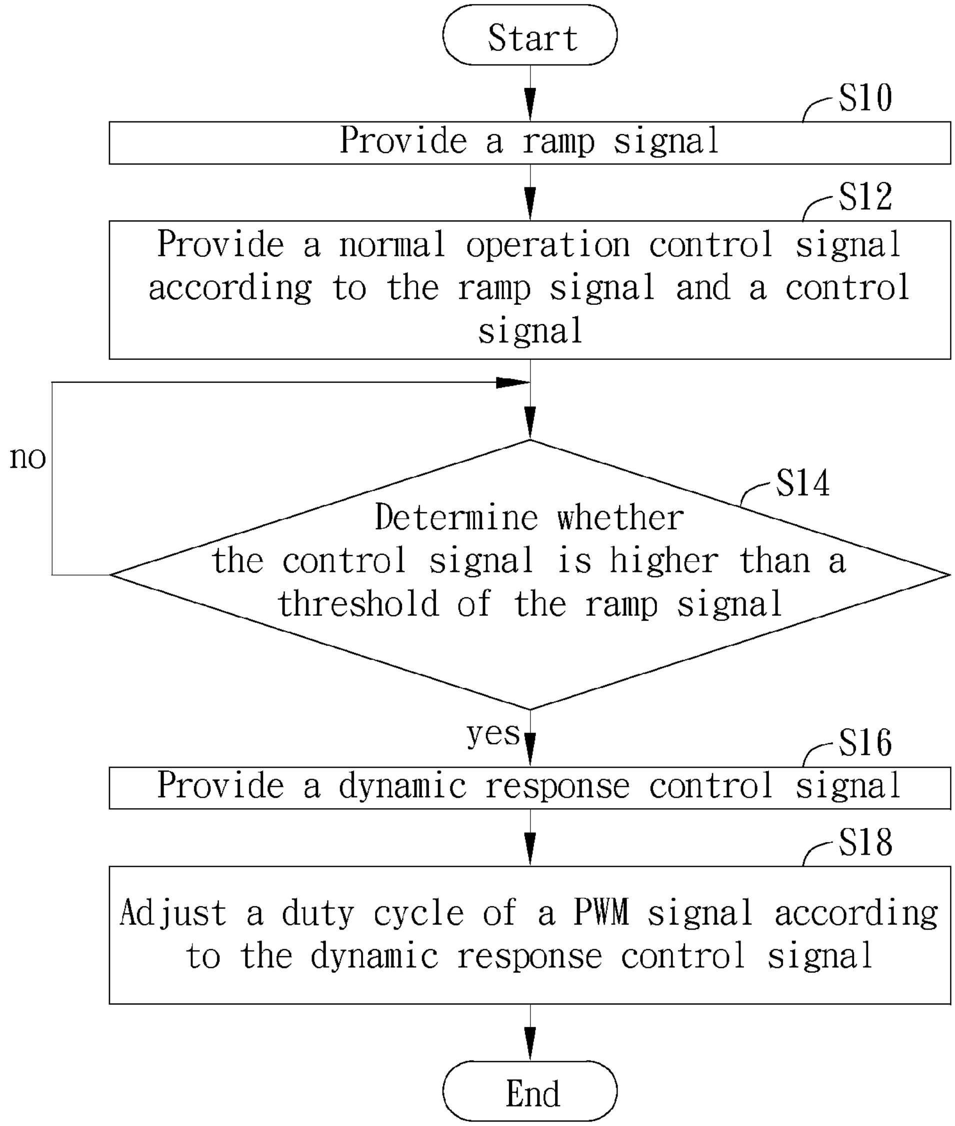

Start
S10
Provide a ramp signal
S12
Provide a normal operation control signal according to the ramp signal and a control signal
no
S14
Determine whether the control signal is higher than a threshold of the ramp signal
yes
S16
Provide a dynamic response control signal
S18
Adjust a duty cycle of a PWM signal according to the dynamic response control signal
End

FIG. 8

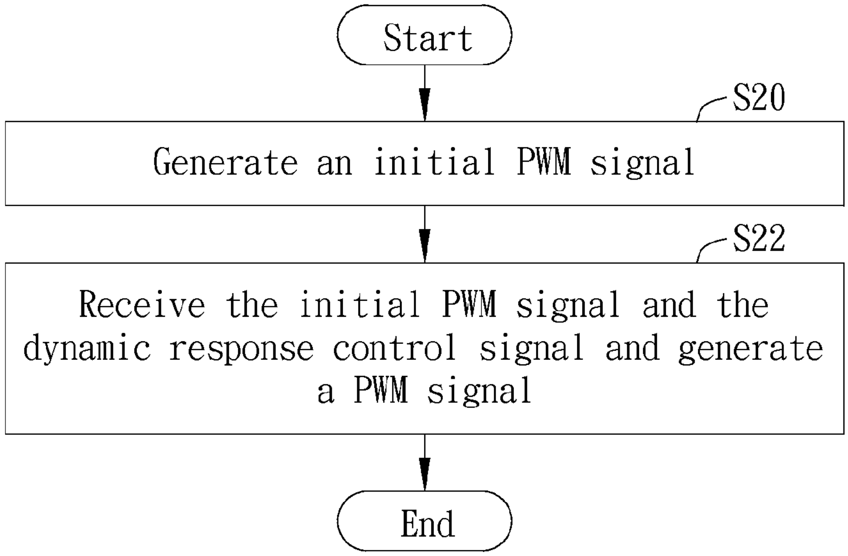

Start
S20
Generate an initial PWM signal
S22
Receive the initial PWM signal and the dynamic response control signal and generate a PWM signal
End

FIG. 9A

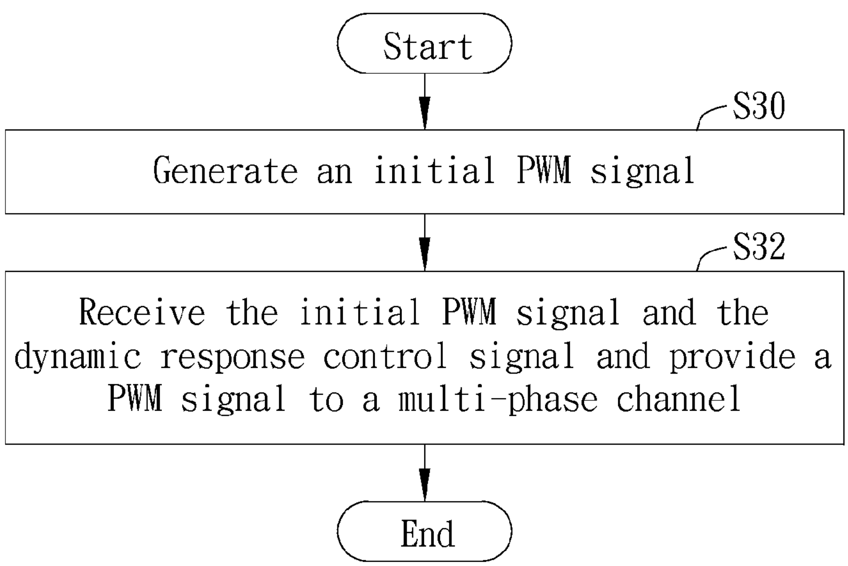

Start
S30
Generate an initial PWM signal
S32
Receive the initial PWM signal and the dynamic response control signal and provide a PWM signal to a multi-phase channel
End

FIG. 9B

# POWER CONVERTER AND OPERATING METHOD THEREOF

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a DC-DC converter; in particular, to a power converter having an improved transient response and an operating method thereof

2. Description of the Prior Art

In recent years, power supply circuits have been widely used in different electronic products, such as portable electronic products, or computer products. The power supply circuit can provide voltage or current conversion or provide power of fixed voltage or current for the electronic products to operate. In the power supply circuits, a power integrated circuit is one of the necessary active components.

U.S. Pat. No. 6,696,825 discloses a DC-DC converter having a feature of forming an adjustable voltage range between a first voltage higher than the output voltage and a second voltage lower than the output voltage and detecting instant changes of the output voltage by a comparator circuit to generate corresponding change of pulse modulation width to drive the transistor to change the output current and the output voltage. Please refer to FIG. **1**. FIG. **1** shows the circuit structure of the DC-DC converter.

As shown in FIG. **1**, in order to have the function of generating real-time dynamic reaction to outer voltage changes, the DC-DC converter **20** in U.S. Pat. No. 6,696,825 needs an additional pin P to direct the output voltage $V_{out}$ into the IC **55**, and uses a specific detection circuit in the IC **55** to detect and analyze the output voltage $V_{out}$, then the DC-DC converter **20** determines the change of the pulse modulation width and takes appropriate response measure to achieve the aim of real-time dynamic reaction. However, the area and cost of the IC will be increased due to the disposing of additional pin P and specific detection circuit.

Therefore, the invention provides a power converter and an operating method thereof to solve the above-mentioned problems occurred in the prior arts.

## SUMMARY OF THE INVENTION

A scope of the invention is to provide a power converter. In a preferred embodiment, the power converter includes a ramp generating unit, a first comparator, a second comparator, and a pulse width modulation (PWM) signal generating unit. The first comparator is coupled to the ramp generating unit. The second comparator is coupled to the ramp generating unit. The PWM signal generating unit is coupled to the first comparator and the second comparator.

The ramp generating unit is used for providing a ramp signal. The first comparator is used for receiving the ramp signal and a control signal to provide a normal operation control signal, wherein the control signal is related to an output voltage of the power converter and a reference voltage. The second comparator is used for receiving the ramp signal and the control signal to provide a dynamic response control signal. The PWM signal generating unit is used for generating a PWM signal according to the normal operation control signal or the dynamic response control signal. When the control signal is higher than a threshold of the ramp signal, the second comparator provides the dynamic response control signal to the PWM signal generating unit to control the PWM signal generating unit to adjust a duty cycle of the PWM signal.



In an embodiment, the PWM signal generating unit includes a PWM signal generator, the PWM signal generator is coupled to the first comparator and used for generating an initial PWM signal, and a duty cycle of the initial PWM signal is dynamically changed with an output load of the power converter.

In an embodiment, the power converter includes an error amplifier and a compensating unit, the error amplifier is used for providing the control signal, and the compensating unit is coupled to an output terminal of the error amplifier.

In an embodiment, when the power converter is a single-phase DC-DC converter, the PWM signal generating unit includes a logic unit and a PWM signal generator, the PWM signal generator is used for generating an initial PWM signal, and the logic unit receives the initial PWM signal and the dynamic response control signal and generates the PWM signal.

In an embodiment, when the power converter is a multi-phase DC-DC converter, the PWM signal generating unit includes a PWM signal generator and a phase channel selection unit, the PWM signal generator is used for generating an initial PWM signal, and the phase channel selection unit receives the initial PWM signal and the dynamic response control signal and provides the PWM signal to a multi-phase channel, wherein a duty cycle of the PWM signal of each phase is dynamically changed with the initial PWM signal and the dynamic response control signal.

A scope of the invention is to provide an operating method for a power converter. The method includes steps of: (a) providing a ramp signal; (b) providing a normal operation control signal according to the ramp signal and a control signal, wherein the control signal is related to an output voltage of the power converter and a reference voltage; (c) determining whether the control signal is higher than a threshold of the ramp signal; (d) when the determining result of step (c) is yes, providing a dynamic response control signal; (e) adjusting a duty cycle of a PWM signal according to the dynamic response control signal, wherein the PWM signal is generated according to the normal operation control signal or the dynamic response control signal.

Compared to the prior arts, the power converter and operating method thereof disclosed in the invention can determine the change of the pulse modulation width and take appropriate response measure according different output voltages without additional pins and specific detection circuit; therefore, it can have advantages of real-time dynamic response, reducing area and cost of IC. In addition, the simple circuit used in the power converter of the invention can enhance the reliability of IC and the error detection and correction, and it can have higher versatility to be applied to all single-phase converters and multi-phase converters.

The advantage and spirit of the invention may be understood by the following detailed descriptions together with the appended drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a schematic diagram of a circuit structure of a conventional power converter.

FIG. **2**A and FIG. **2**B illustrate schematic diagrams of a circuit structure of a power converter in an embodiment of the invention.

FIG. **3** illustrates a detailed functional block diagram of the PWM signal generating unit **102** in FIG. **2**B.

FIG. **4** illustrates a detailed functional block diagram of the phase channels ST**1**~STN of the multi-phase channel **12** in FIG. **2**B.

FIG. **5** illustrates a detailed functional block diagram of the compensating unit **104** in FIG. **2**B.

FIG. **6**A illustrates a wave form diagram of the signals of the single-phase DC-DC converter under the condition of low loading current $I_{LD}$; FIG. **6**B illustrates a wave form diagram of the signals of the single-phase DC-DC converter under the condition of high loading current $I_{LD}$; FIG. **6**C illustrates a wave form diagram of the signals of the single-phase DC-DC converter under the condition of changing high and low loading current $I_{LD}$.

FIG. **7**A illustrates a wave form diagram of the signals of the three-phase DC-DC converter under the condition of low loading current $I_{LD}$; FIG. **7**B illustrates a wave form diagram of the signals of the three-phase DC-DC converter under the condition of high loading current $I_{LD}$; FIG. **7**C illustrates a wave form diagram of the signals of the three-phase DC-DC converter under the condition of changing high and low loading current $I_{LD}$.

FIG. **8** illustrates a flowchart of the operating method for the power converter in another embodiment of the invention.

FIG. **9**A and FIG. **9**B illustrate a flowchart of the operating method generating the PWM signal when the power converter is a single-phase DC-DC converter or a multi-phase DC-DC converter respectively.

## DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the invention is a power converter. In fact, the power converter of the invention is applied in a power IC, but not limited to this. The invention can be applied in power conversion circuit structures of the AC-DC converter or the DC-AC converter.

Please refer to FIG. **2**A and FIG. **2**B. FIG. **2**A and FIG. **2**B illustrate schematic diagrams of a circuit structure of a power converter in the invention. As shown in FIG. **2**A, the DC-DC converter **1** is used to convert the input voltage $V_{in}$ received by the voltage input terminal $N_{in}$ into the output voltage $V_{out}$ and the output voltage $V_{out}$ is outputted from the voltage output terminal $N_{out}$.

As shown in FIG. **2**B, the DC-DC converter **1** includes a pulse width modulation (PWM) controller **10**, a multi-phase channel **12**, an output resistor $R_{out}$, an output capacitor $C_{out}$, and a load LD. The PWM controller **10** includes a ramp generating unit **100**, a PWM signal generating unit **102**, a compensating unit **104**, an amplifying unit **106**, a first comparator **108**, and a second comparator **110**. The multi-phase channel **12** includes N channels ST**1**~STN aligned in parallel. The output capacitor $C_{out}$ has lower equivalent capacitance resistance, and the output resistor $R_{out}$ is the equivalent series resistance (ESR) of the output capacitor $C_{out}$. A load current $I_{LD}$ is the current flowing through the load LD.

In this embodiment, the ramp generating unit **100** can be replaced by a triangle wave generating unit or a sawtooth wave generating unit. The amplifying unit **106** can be an error amplifier or a transconductance amplifier or other equivalent circuits.

The PWM controller **10** is coupled to the multi-phase channel **12** and the voltage output terminal $N_{out}$. The multi-phase channel **12** is coupled between the voltage input terminal $N_{in}$ and the voltage output terminal $N_{out}$. The output resistor $R_{out}$ and the output capacitor $C_{out}$ are coupled in series between the third node N**3** and the ground G, and the third node N**3** is between the multi-phase channel **12** and the voltage output terminal $N_{out}$. The load LD is coupled between the fourth node N**4** and the ground G, and the fourth node N**4** is between the multi-phase channel **12** and the voltage output terminal $N_{out}$. The ramp generating unit **100** is coupled to the first comparator **108**, the second comparator **110**, and the N channels ST**1**~STN of the multi-phase channel **12**. The PWM signal generating unit **102** is coupled to the first comparator **108**, the second comparator **110**, and the N channels ST**1**~STN of the multi-phase channel **12**. The compensating unit **104** is coupled to the amplifying unit **106**, the first comparator **108**, and the second comparator **110**. The amplifying unit **106** is coupled to the reference voltage $V_{ref}$, the voltage output terminal $N_{out}$, and the voltage output terminal $N_{out}$. The first comparator **108** is coupled to the ramp generating unit **100**, the compensating unit **104**, and the PWM signal generating unit **102**. The second comparator **110** is coupled to the ramp generating unit **100**, the compensating unit **104**, and the PWM signal generating unit **102**.



In the PWM controller **10**, the first input terminal and the second input terminal of the amplifying unit **106** receive the reference voltage $V_{ref}$ and the output voltage $V_{out}$ from the voltage output terminal $N_{out}$ respectively, and the amplifying unit **106** generates a control signal $V_{ref}$ according to the voltage difference between the reference voltage $V_{ref}$ and the output voltage $V_{out}$. That is to say, the control signal $V_{ER}$ outputted by the amplifying unit **106** relates to the output voltage $V_{out}$ of the DC-DC converter **1** and the reference voltage $V_{ref}$. In this embodiment, the output voltage $V_{out}$ can be also an output feedback voltage or a feedback voltage ($V_{FB}$).

The control signal $V_{ER}$ generated by the amplifying unit **106** is compensated by the compensating unit **104** and then outputted to the first input terminal of the first comparator **108** and the first input terminal of the second comparator **110**. The ramp generating unit **100** is used to generate the ramp signal. In this embodiment, the ramp signal generated by the ramp generating unit **100** is $S_R$ or a ramp top signal $S_{RT}$ having a (top) threshold value. The ramp signal $S_R$ generated by the ramp generating unit **100** is outputted to the second input terminal of the first comparator **108**, and the ramp top signal $S_{RT}$ generated by the ramp generating unit **100** is outputted to the second input terminal of the second comparator **110**.

When the first input terminal and the second input terminal of the first comparator **108** receive the control signal $V_{ER}$ outputted by the amplifying unit **106** and the ramp signal $S_R$ generated by the ramp generating unit **100** respectively, the first comparator **108** determines whether the magnitude of the control signal $V_{ER}$ is higher than the ramp signal $S_R$. If the determining result of the first comparator **108** is yes, the first comparator **108** will output a normal operation control signal (a trigger signal) $S_{TR}$ to the PWM signal generating unit **102**. When the PWM signal generating unit **102** receives the normal operation control signal $S_{TR}$, the PWM signal generating unit **102** generates a PWM signal according to the normal operation control signal $S_{TR}$.

When the first input terminal and the second input terminal of the second comparator **110** receive the control signal $V_{ER}$ outputted by the amplifying unit **106** and the ramp top signal $S_{RT}$ having the (top) threshold value generated by the ramp generating unit **100** respectively, the second comparator **110** determines whether the magnitude of the control signal $V_{ER}$ is higher than the (top) threshold value of the ramp top signal $S_{RT}$. If the determining result of the second comparator **110** is yes, the second comparator **110** will output a dynamic response control signal $S_{TB}$ to the PWM signal generating unit **102**. When the PWM signal generating unit **102** receives the dynamic response control signal $S_{TB}$, the PWM signal generating unit **102** will adjust the duty cycle of the PWM signal according to the dynamic response control signal $S_{TB}$, so that at some time points, the angle between the control signal $V_{ER}$ and the ramp signal $S_R$ will be larger to reduce the interference of noise to enhance its signal-to-noise ratio (SNR).

It should be noticed that the PWM signal generating unit **102** actually generates PWM signals $S_{PWM1}$~$S_{PWMN}$ according to the normal operation control signal $S_{TR}$, the dynamic response control signal $S_{TB}$, the input voltage $V_{in}$, and the output voltage $V_{out}$. The PWM signal generating unit **102** correspondingly outputs the PWM signals $S_{PWM1\sim SPWMN}$ to the channels ST**1**~STN of the multi-phase channel **12** respectively. The ramp generating unit **100** can generate the ramp signal $S_R$ according to the PWM signals $S_{PWM1}$~$S_{PWMN}$, the input voltage $V_{in}$, and the output voltage $V_{out}$. In other embodiments, the ramp generating unit **100** can generate the ramp signal $S_R$ without coupling to the input voltage and the output voltage.

Next, please refer to FIG. **3**. FIG. **3** illustrates a detailed functional block diagram of the PWM signal generating unit **102** in FIG. **2**B. It should be noticed that FIG. **3** is used for the multi-phase DC-DC converter, and it is only an embodiment of the PWM signal generating unit **102** of the invention, but not limited to this. As shown in FIG. **3**, the PWM signal generating unit **102** includes a PWM signal generator **102**A, a phase channel current sensing unit **102**B, and a phase channel selection unit **102**C.

The PWM signal generator **102**A is coupled to the first comparator **108**, the phase channel current sensing unit **102**B, and the phase channel selection unit **102**C. The phase channel current sensing unit **102**B is coupled to the PWM signal generator **102**A, the phase channel selection unit **102**C, the inductances L**1**~LN in the channels ST**1**~STN of the multi-phase channel **12**. (See FIG. **4**) The phase channel selection unit **102**C is coupled to the PWM signal generator **102**A, the phase channel current sensing unit **102**B, and the channels ST**1**~STN of the multi-phase channel **12**.

In this embodiment, the PWM signal generator **102**A is used to generate an initial PWM signal $S_{PWM0}$; the phase channel current sensing unit **102**B is used to sense inductance currents $I_1$~$I_N$ flowing through the inductances L**1**~LN in the channels ST**1**~STN of the multi-phase channel **12**, and calculate them to obtain error currents $IB_1$~$IB_N$ among the channels ST**1**~STN, and direct the error currents $IB_1$~$IB_N$ into the PWM signal generator **102**A for the PWM signal generator **102**A to adjust its duty cycle of generating the initial PWM signal $S_{PWM0}$. The phase channel selection unit **102**C receives the initial PWM signal $S_{PWM0}$ from the PWM signal generator **102**A and the dynamic response control signal $S_{TB}$ from the second comparator **110** and provides the PWM signals $S_{PWM1}$~$S_{PWMN}$ to the channels ST**1**~STN of the multi-phase channel **12**.

Please refer to FIG. **4**. FIG. **4** illustrates a detailed functional block diagram of the phase channels ST**1**~STN of the multi-phase channel **12** in FIG. **2**B. It should be noticed that FIG. **4** is only an embodiment of the channels ST**1**~STN of the multi-phase channel **12** in this invention, but not limited to this. As shown in FIG. **4**, the channels ST**1**~STN of the multi-phase channel **12** are all coupled between the voltage input terminal $N_{in}$ and the voltage output terminal $N_{out}$, and the channels ST**1**~STN are coupled to the phase channel selection unit **102**C to receive the PWM signals $S_{PWM1}$~$S_{PWMN}$ respectively. The duty cycles of the PWM signals $S_{PWM1}$~$S_{PWMN}$ of each of the channels ST**1**~STN is dynamically varied with the initial PWM signal $S_{PWM0}$ and the dynamic response control signal $S_{TB}$, but not limited to this.

In practical applications, the duty cycle of the initial PWM signal $S_{PWM0}$ generated by the PWM signal generator **102**A is dynamically varied with the output load LD of the DC-DC converter **1**. That is to say, under the condition of weightier output load LD, the duty cycle of the initial PWM signal $S_{PWM0}$ will become larger, and the distribution of the initial PWM signal $S_{PWM0}$ will also become denser. When transient is occurred, the second comparator **110** outputs the dynamic response control signal $S_{TB}$ to the PWM signal generating unit **102**. Because the PWM signal generating unit **102** generates the PWM signals $S_{PWM1}$~$S_{PWMN}$ of each of the channels ST**1**~STN according to the initial PWM signal $S_{PWM0}$ and the dynamic response control signal $S_{TB}$, the distribution of the PWM signals $S_{PWM1}$~$S_{PWMN}$ of each of the channels ST**1**~STN will also become denser and the output of each of the channels ST**1**~STN will also become larger. Therefore, the output current will become larger and the output voltage can be drawn back to the default adjustment value to improve the transient response of the DC-DC converter **1**.

The first channel ST**1** of the multi-phase channel **12** includes a control unit CU**1**, a first switch MU**1**, a second switch ML**1**, and an inductance L**1**. The control unit CU**1** is coupled to the phase channel selection unit **102**C, the first switch MU**1**, and the second switch ML**1** of the PWM signal generating unit **102**. The first switch MU**1** and the inductance L**1** are connected in series between the voltage input terminal $N_{in}$, and the voltage output terminal $N_{out}$. The second switch ML**1** is coupled between the fifth node **N51** and the ground G, and the fifth node **N51** is located between the first switch MU**1** and the inductance L**1**.

Similarly, the second channel ST**2** of the multi-phase channel **12** includes a control unit CU**2**, a first switch MU**2**, a second switch ML**2**, and an inductance L**2**. The control unit CU**2** is coupled to the phase channel selection unit **102**C of the PWM signal generating unit **102**, the first switch MU**2**, and the second switch ML**2**. The first switch MU**2** and the inductance L**2** are connected in series between the voltage input terminal $N_{in}$ and the voltage output terminal $N_{out}$. The second switch ML**2** is coupled between the fifth node **N52** and the ground G, and the fifth node **N52** is located between the first switch MU**2** and the inductance L**2**. And so on, this is not otherwise repeated.

It should be noticed that the first switches MU**1**~MUN and the second switches ML**1**~MLN of the channels ST**1**~STN of the multi-phase channel **12** can be all N-type transistors, all P-type transistors, or combination of N-type transistors and P-type transistors. There is no specific limitation. When the control units CU**1**~CUN of the channels ST**1**~STN of the multi-phase channel **12** receive the PWM signals $S_{PWM1}$~$S_{PWMN}$ from the PWM signal generating unit **102** respectively, the control units CU**1**~CUN of the channels ST**1**~STN will control their own first switches MU**1**~MUN and second switches ML**1**~MLN to be conductive or shut down according to the PWM signals $S_{PWM1}$~$S_{PWMN}$ respectively.

Please refer to FIG. **5**. FIG. **5** illustrates a detailed functional block diagram of the compensating unit **104** in FIG. **2**B. It should be noticed that FIG. **5** is only an embodiment of the compensating unit **104** of the invention, but not limited to this. As shown in FIG. **5**, the compensating unit **104** includes a compensating resister $R_{CP}$, first compensating capacitor $C_{CP1}$, and a second compensating capacitor $C_{CP2}$. The compensating resister $R_{CP}$ and the first compensating capacitor $C_{CP1}$ are connected in series between the first node $N_1$ and the ground G. The second compensating capacitor $C_{CP2}$ is coupled between the second node $N_2$ and the ground G. The first node $N_1$ and the second node $N_2$ are both located between the amplifying unit **106** and the first comparator **108**.

In an embodiment, it is assumed that the DC-DC converter **1** in FIG. **2**A is a single-phase DC-DC converter; that is to say, the output stage of the DC-DC converter only includes one channel. At this time, the PWM signal generating unit **102** of the DC-DC converter **1** includes the PWM signal generator **102**A and a logic unit (not shown). The PWM signal generator **102**A generates the initial PWM signal $S_{PMW0}$; the logic unit receives the initial PWM signal $S_{PWM0}$ and the dynamic response control signal $S_{TB}$ and generates the PWM signal $S_{PWM0}$ to the single-phase channel. Please refer to FIG. **6**A~FIG. **6**C. FIG. **6**A illustrates a wave form diagram of the signals of the single-phase DC-DC converter **1** under the condition of low loading current $I_{LD}$; FIG. **6**B illustrates a wave form diagram of the signals of the single-phase DC-DC converter **1** under the condition of high loading current $I_{LD}$; FIG. **6**C illustrates a wave form diagram of the signals of the single-phase DC-DC converter **1** under the condition of changing high and low loading current $I_{LD}$.

From FIG. **6**A~FIG. **6**C, it can be known that no matter the single-phase DC-DC converter **1** is operated under the condition of high loading current, low loading current, or changing high and low loading current, after the amplifying unit **106** is used to generate the control signal $V_{ER}$, the single-phase DC-DC converter **1** compares the control signal $V_{ER}$ with the ramp signal $S_R$ and the ramp top signal $S_{RT}$ respectively, and then uses the dynamic response control signal $S_{TB}$ and the initial PWM signal $S_{PWM0}$ to adjust the duty cycle of the PWM signal $S_{PWM}$ according to the compared result. Therefore, at some time points, the angle between the control signal $V_{ER}$ and the ramp signal $S_R$ becomes larger to effectively avoid the interference of noise and increase the signal-to-noise ratio (SNR).

In another embodiment, it is assumed that the DC-DC converter **1** in FIG. **2**A is a multi-phase DC-DC converter shown in FIG. **2**B; that is to say, the output stage **12** of the DC-DC converter **1** includes N channels ST**1**~STN. Please refer to FIG. **7**A~FIG. **7**C. It is assumed that N=3, namely the output stage **12** of the DC-DC converter **1** includes 3 channels ST**1**~ST**3**. FIG. **7**A illustrates a wave form diagram of the signals of the three-phase DC-DC converter **1** under the condition of low loading current $I_{LD}$; FIG. **7**B illustrates a wave form diagram of the signals of the three-phase DC-DC converter **1** under the condition of high loading current $I_{LD}$; FIG. **7**C illustrates a wave form diagram of the signals of the three-phase DC-DC converter **1** under the condition of changing high and low loading current $I_{LD}$.

From FIG. **7**A~FIG. **7**C, it can be known that no matter the three-phase DC-DC converter **1** is operated under the condition of high loading current, low loading current, or changing high and low loading current, after the amplifying unit **106** is used to generate the control signal $V_{ER}$, the three-phase DC-DC converter **1** compares the control signal $V_{ER}$ with the ramp signal $S_R$ and the ramp top signal $S_{RT}$ respectively, and then uses the dynamic response control signal $S_{TB}$ and the initial PWM signal $S_{PWM0}$ cooperated with the phase channel selection unit **102**C to adjust and select the duty cycle of the PWM signal $S_{PWM}$ according to the compared result. Therefore, at some time points, the angle between the control signal $V_{ER}$ and the ramp signal $S_R$ becomes larger to effectively avoid the interference of noise and increase the signal-to-noise ratio (SNR).

Another embodiment of the invention is a power converter operating method. In this embodiment, the power converter operating method is used in a power IC to operate a power converter. The power converter is coupled to a voltage output terminal and a multi-phase channel. The multi-phase channel is coupled between a voltage input terminal and the voltage output terminal The multi-phase channel includes a plurality of parallel phase channels. A plurality of input terminals and output terminals of the plurality of phase channels are coupled to the voltage input terminal and the voltage output terminal respectively.

Please refer to FIG. **8**. FIG. **8** illustrates a flowchart of the power converter operating method. As shown in FIG. **8**, in step S**10**, the method provides a ramp signal. In step S**12**, the method provides a normal operation control signal according to the ramp signal and a control signal. In fact, the control signal is related to an output voltage of the power converter and a reference voltage. For example, the control signal can be generated according to the reference voltage and the output voltage from the voltage output terminal of the power converter, but not limited to this. In addition, the method can also compensate the control signal.

In step S**14**, the method determines whether the control signal is higher than a threshold of the ramp signal. If the determining result of step S**14** is yes, the method will perform step S**16** to provide a dynamic response control signal. Then, the method will perform step S**18** to adjust a duty cycle of a PWM signal according to the dynamic response control signal. The PWM signal is generated according to the normal operation control signal or the dynamic response control signal. Then, the plurality of input terminals of the plurality of phase channels in the multiple channel will receive the output voltage from the voltage input terminal and receive a PWM signal from the power converter respectively, and the plurality of output terminals of the plurality of phase channels in the multiple channel will output the output signal to the voltage output terminal.

In practical applications, the PWM signal generating step of the method will be different based on whether the power converter is a single-phase DC-DC converter or a multi-phase DC-Dc converter, described as follows:

As shown in FIG. **9**A, if the power converter is the single-phase DC-DC converter, the method will perform step S**20** to generate an initial PWM signal. In fact, a duty cycle of the initial PWM signal will be dynamically varied with the output loading of the power converter, but not limited to this. Then, the method will perform step S**22** to receive the initial PWM signal and the dynamic response control signal and generate a PWM signal. It should be noticed that the dynamic response control signal in step S**22** is the dynamic response control signal provided in step S**16**.

As shown in FIG. **9**B, if the power converter is the multi-phase DC-DC converter, the method will perform step S**30** to generate an initial PWM signal. In fact, a duty cycle of the initial PWM signal will be dynamically varied with the output loading of the power converter, but not limited to this. Then, the method will perform step S**32** to receive the initial PWM signal and the dynamic response control signal and provide a PWM signal to a multi-phase channel. Wherein, the duty cycle of the initial PWM signal of each phase will be dynamically varied with the initial PWM signal and the dynamic response control signal.

Compared to the prior arts, the power converter and operating method thereof disclosed in the invention can determine the change of the pulse modulation width and take appropriate response measure according different output voltages without additional pins and specific detection circuit; therefore, it can have advantages of real-time dynamic response, reducing area and cost of IC. In addition, the simple circuit used in the power converter of the invention can enhance the reliability of IC and the error detection and correction, and it can have higher versatility to be applied to all single-phase converters and multi-phase converters.

With the example and explanations above, the features and spirits of the invention will be hopefully well described. Those skilled in the art will readily observe that numerous modifications and alterations of the device may be made while retaining the teaching of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

**1**. A power converter, comprising:

a ramp generating unit, for providing a ramp signal;

a first comparator, coupled to the ramp generating unit and receiving the ramp signal and a control signal to provide a normal operation control signal, wherein the control signal is related to an output voltage of the power converter and a reference voltage;

a second comparator, coupled to the ramp generating unit and receiving the ramp signal and the control signal to provide a dynamic response control signal; and

a pulse width modulation (PWM) signal generating unit, coupled to the first comparator and the second comparator and generating a PWM signal according to the normal operation control signal or the dynamic response control signal;

wherein when the magnitude of the control signal is higher than a threshold of the ramp signal, the second comparator provides the dynamic response control signal to the PWM signal generating unit to control the PWM signal generating unit to adjust a duty cycle of the PWM signal.

**2**. The power converter of claim **1**, wherein the PWM signal generating unit comprises a PWM signal generator, the PWM signal generator is coupled to the first comparator and used for generating an initial PWM signal, and a duty cycle of the initial PWM signal is dynamically changed with an output load of the power converter.

**3**. The power converter of claim **1**, further comprising an error amplifier and a compensating unit, the error amplifier is used for providing the control signal, and the compensating unit is coupled to an output terminal of the error amplifier.

**4**. The power converter of claim **1**, wherein when the power converter is a single-phase DC-DC converter, the PWM signal generating unit comprises a logic unit and a PWM signal generator, the PWM signal generator is used for generating an initial PWM signal, and the logic unit receives the initial PWM signal and the dynamic response control signal and generates the PWM signal.

**5**. The power converter of claim **1**, wherein if the power converter is a multi-phase DC-DC converter, the PWM signal generating unit comprises a PWM signal generator and a phase channel selection unit, the PWM signal generator is used for generating an initial PWM signal, and the phase channel selection unit receives the initial PWM signal and the dynamic response control signal and provides the PWM signal to a multi-phase channel, wherein a duty cycle of the PWM signal of each phase is dynamically changed with the initial PWM signal and the dynamic response control signal.

**6**. An operating method for a power converter, the operating method comprising steps of:

(a) providing a ramp signal;

(b) providing a normal operation control signal according to the ramp signal and a control signal, wherein the control signal is related to an output voltage of the power converter and a reference voltage;

(c) determining whether the magnitude of the control signal is higher than a threshold of the ramp signal;

(d) if the determining result of step (c) is yes, providing a dynamic response control signal; and

(e) adjusting a duty cycle of a pulse width modulation (PWM) signal according to the dynamic response control signal, wherein the PWM signal is generated according to the normal operation control signal or the dynamic response control signal.

**7**. The operating method of claim **6**, further comprising the step of:

generating an initial PWM signal, and a duty cycle of the initial PWM signal is dynamically changed with an output load of the power converter.

**8**. The operating method of claim **6**, further comprising the step of:

generating the control signal according to the output voltage of the power converter and the reference voltage; and

compensating the control signal.

**9**. The operating method of claim **6**, wherein if the power converter is a single-phase DC-DC converter, the method further comprises the steps of:

generating an initial PWM signal; and

receiving the initial PWM signal and the dynamic response control signal and generating the PWM signal.

**10**. The operating method of claim **6**, wherein if the power converter is a multi-phase DC-DC converter, the method further comprises the steps of:

generating an initial PWM signal; and

receiving the initial PWM signal and the dynamic response control signal and providing the PWM signal to a multi-phase channel;

wherein a duty cycle of the PWM signal of each phase is dynamically changed with the initial PWM signal and the dynamic response control signal.

**11**. The power converter of claim **1**, wherein if the power converter is a multi-phase DC-DC converter, the PWM signal generating unit provides the PWM signal to a multi-phase channel having a plurality of phase channels, when the PWM signal generating unit receives the dynamic response control signal, a duty cycle of the PWM signal in a first phase channel of the multi-phase channel is the same with that in other phase channels of the multi-phase channel, so the power converter can provide enough energy to an output load of the power converter.

**12**. A power converter, comprising:

a ramp generating unit, for providing a ramp signal;

a first comparator, coupled to the ramp generating unit and receiving the ramp signal and a control signal to provide a normal operation control signal;

a second comparator, coupled to the ramp generating unit and receiving the ramp signal and the control signal to provide a dynamic response control signal; and

a pulse width modulation (PWM) signal generating unit, coupled to the first comparator and the second comparator and generating a PWM signal according to the normal operation control signal or the dynamic response control signal.

**13**. The power converter of claim **12**, wherein when the magnitude of the control signal is higher than a threshold of the ramp signal, the second comparator provides the dynamic response control signal to the PWM signal generating unit to control the PWM signal generating unit to adjust a duty cycle of the PWM signal.

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